Fermi National Accelerator Laboratory

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T Type Collimator

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INTRODUCTION

For the 1989 fixed target run there will be three experiments that require 800 GeV protons with intensities of 0.1 to 100 MHz. These experiments are: E-771 PWEST, E-690 NEAST, and E-706 MWEST. Given the constraints of existing switchyard and beam line enclosures the use of electrostatic septa, lambertson magnets, or diffractive production of protons to produce these intensities is not possible. The lowest intensity that switchyard can "comfortably" split from the Tevatron beam is on the order of 1 E11 protons per pulse (ppp). By comfortably it is meant that the position and intensity remain stable from pulse to pulse. To achieve the necessary reduction in intensity a new type of pin-hole collimator has been developed by the Research Division (RD).

The pin-hole collimator, also know as a "T type" collimator, consists of a steel block 60 inches long surrounded by a steel shield. Typically there are three holes with sizes on the order of a few hundredths of an inch milled the length of the block. The vertical and horizontal position of block can be remotely adjusted. This allows accurate positioning of the hole using the proton beam. The underlying principle is to allow only a small fraction of the beam to pass through the hole while the majority of the beam interacts in the steel. The exact sizes of the holes are determined by;

- The size of the beam where the pin-hole will be installed
- The range of intensities required by each experiment
- The Single Pulse Accident Condition (SPAC) for each beam line

The size of the beam spot is determined by SWIC information from previous runs. The ratio of the area of the beam to area of the hole gives the desired attenuation factor. Both PWEST and MWEST require variable intensity under experimenter control. Since it is the policy of research division not to allow experimenters to tune primary proton beam, two T type collimators will be used in each beam line. The first device will attenuate the proton beam to less than 1 E9 ppp. This intensity is at the level of a secondary beam. The second T type collimator can be controlled by the experimenters to give the desired intensity.

The Single Pulse Accident Condition requires that if the entire beam in the Tevatron is dumped in one millisecond no area exceeds the dose rate specified in the Fermilab radiation guide (1). The one millisecond is the time needed for fast extraction, i.e. a ping. For the 1989 run the maximum machine intensity is taken to be 2.5 E13 protons. The radiation safety officer determines the weakest point in the shielding, and calculates how many protons accidently dumped at that point would cause an unacceptable dose rate. The ratio of maximum machine intensity to accident intensity gives the required attenuation for the beam line. For instance in MWEST the SPAC requires that no more than 1.25 E10 protons be dumped downstream of the MESON detector building. The two T type collimators must provide an attenuation factor of 2000 and be located upstream of the Meson Detector building. For PWEST the beam line and experiment has sufficient shielding that there is no required attenuation for radiation safety.

These three conditions then determine the hole sizes, the incident proton intensity, and the shielding needed. See table 1a and b for the details.

MOTION OF THE BLOCK

To give the maximum flexibility the pin-hole block has independent motor drives at each end for both the horizontal and vertical directions. The total horizontal motion is one inch, the total vertical motion is four inches. With the combined motion all four edges of each hole can be move out of the beam. Transmission verses position curves show clean edges for all the holes. This aids with location and alignment of the block. To achieve this sort of motion the block is suspended from a T shaped piece of steel, giving the name "T type".

The horizontal drives are attached to the shield and push on the top of the T see figure 1. The T slides over pad of DU (2), this is a material that has a coefficient of sliding friction of 0.2 allowing for smooth horizontal motion. The vertical motor drives, screw jacks, and position sensors ride on the top of the T. The block is held by stainless steel end caps attached to screw jacks. The end caps slide between bronze plates mounted in the base of the T. The motion in both vertical and horizontal planes are monitored by Linear Variable Differential Transformers (LVDT) these provide position information for the beam line control system (EPICURE). The entire shield is placed on CERN adjusters to allow for accurate placement in the beam line.

STEEL SHIELD

The pin-hole block will become radioactive after a short time. To protect the environment and personnel a steel shield surrounds the block. The thickness of the shield is determined by the computer program CASIM (3). The important considerations are to keep the ground water activation and the personnel exposure in line with the Fermilab radiation safety manual. An entrance shield 12 inches thick is used to prevent personal exposure to the front face. In addition the shield length and width allows the entire assembley to be moved as a unit from the assembly shops to the beam enclosure. In the event of failure the T and block can be removed from the shield either by lifting out, or by removing the front shield and sliding forward. If the block is radioactive the T assembly is put into a steel box (coffin) with four inch thick walls. The coffin can be moved by truck to the Fermilab hot shop where the pin-hole block can be detached by remote handling devices.

PIN HOLE BLOCK

The pin hole block is made of steel 4 x 4 inches by 60 inches long. The length reduces the beam punch through to an acceptable level. The block is split down the center (figure 2) to prevent excessive sagging that could occlude the smaller holes. To aid in assembly and alignment the holes were all milled in one side of the block. The surveyors can reference one side of each hole by finding the center line of the block. The block is held by pins at each end. There is sufficient clearance for the block and the drive screws to prevent jamming under the extreme condition of the drives being at the opposite ends of their limits. To protect the stepping motors there are power cut off switches external to the T that will stop the motors at the end of travel. The motor controller is designed so that the drives can be reversed and the block returned to nominal positions. Monte Carlo calculation for beam heating effects indicated a worst case temperature rise of 500 centigrade at twice the normal proton intensity (2 E12 ppp). This translates into a 0.0015 inch sag at the center of the block.

COST ESTIMATES

The steel used for the shield is from the Fermilab stock pile. It was flame cut to rough size on site and shipped to an outside vendor for machining and assembly, see table 2 for cost breakdown. A total of 400 hours of machine time was required. Table 3 list the print numbers for the shield assembly. The pin hole block was made at the Fermilab Central shops, using stress relieved hot rolled steel. Hot rolled steel was chosen to reduce sagging during normal operation of the pin-hole. Fabrication on site allowed careful inspection by the survey group during manufacture of the block. The stepping motors and LVDTs are commercially available items purchased by the RD EED group. The entire device is assembled in the RD shops and fully tested before installation in the beam line enclosure.

SUMMARY

The Research Division has developed a pin-hole collimator capable of attenuating the 800 GeV proton beam by a factor of ten to one hundered. A bid package has been let for the first prototype has been sent out. The other four collimators will be ordered in the spring of 1989.

TABLE 1a

PIN-HOLE DIMENSIONS

	MO-2	MW-6	NE-8
SPAC	1.25 E10	1.25 E10	2.5 E10
ATTENUATION	2000		1000
INCIDENT PPP	4.0 E11	4.0 E10	1.0 E12
EXITING PPP	4.0 E10	2.0 E8	1 E9
SHIELD RADIUS inches	25	7	7
RESIDUAL ACTIVITY mr/hr	100	< 100	250
MAX BLOCK ACTIVITY mr/hr	5,000	200	5,000
HOLE SIZES inches	0.040 0.080	0.080 0.140 0.200	0.060 0.080 0.125
HOLE SPACING CENTER TO CENTER inches	1.0	0.8	0.7

TABLE 1b

PIN-HOLE DIMENSIONS

	PW-2	PW5
SPAC	-	-
ATTENUATION	-	-
INCIDENT PPP	1 E11	4 E9
EXITING PPP	4 E9	4 E7 - 4 E9
SHIELD RADIUS inches	18	7
RESIDUAL ACTIVITY mr/hr	20-50	<10
MAX BLOCK ACTIVITY mr/hr	500	<50
HOLE SIZES inches	0.05 0.10 0.20	0.080 0.180 0.450
HOLE SPACING CENTER TO CENTER inches	1.0	1.0

For PWEST the SPAC is not a problem. There is sufficient shielding along the beam line to limit outside exposure to less than 50 mr/hr under any condition.

TABLE 2

Cost estimate for the T type collimator.

SHIELD

Steel for shield	7,274.40
Steel for T	2,000.00
Grinding sides	1,611.00
Machining 400 hrs @ $33.00/hr	13,200.00
CERN adjusters 3 @ $300.00	900.00
sub-total	$24,985.40

PIN-HOLE BLOCK

Steel (est)	300.00
Machining (est) 40 hrs @ $33.00/hr	1300.00
sub-total	$1600.00

MOTORS AND SENSORS

Stepping motors	2,945.80
LVDTs and connectors	1,401.60
LVDT mounting blocks	572.00
Mounting plates material and labor	2,500.00
Switches	600.00
sub-total	$8,019.40

TABLE 2 (continued)

INSTALLATION

Electricians	(2 crew days)	1,120.00
Rigging	(1 crew day)	1,200.00
Cutting	(1 crew day)	1,200.00
	sub-total	$3,520.00

The bottom line is $40,000.00 to build one T type collimator.

TABLE 3

FNAL DRAWING NUMBERS

9208.150-ME-272403	MAIN ASSEMBLY PIN HOLE
9208.150-MD-272392	LEFT SIDE PLATE
9208.150-MD-272393	RIGHT SIDE PLATE
9208.150-MD-272394	LOWER CENTER PLATE

REFERENCES

(1) FERMILAB RADIATION GUIDE fifth edition March 1988

L Coulson, W Freeman sections 2.2, 2.3, 2.4

(2) GARLOCK INDUSTRIES

(3) CASIM FERMI NATIONAL ACCELERATOR LABORATORY

FN-272 11000.050

FIGURE 1
T TYPE COLLIMATOR

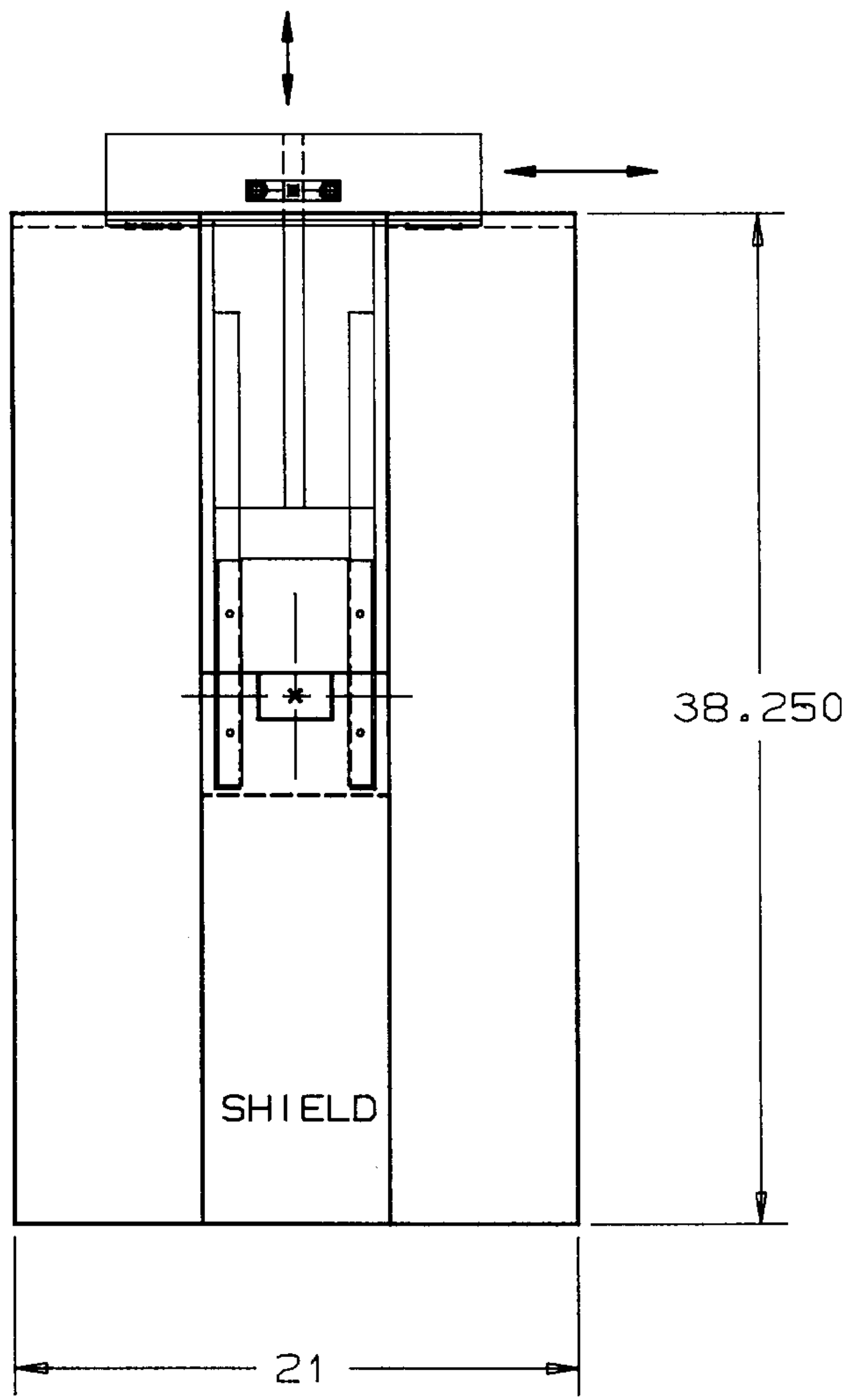

FIGURE 2

PINHOLE BLOCK